Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 RSSC Requirements and Approaches

Lauren White
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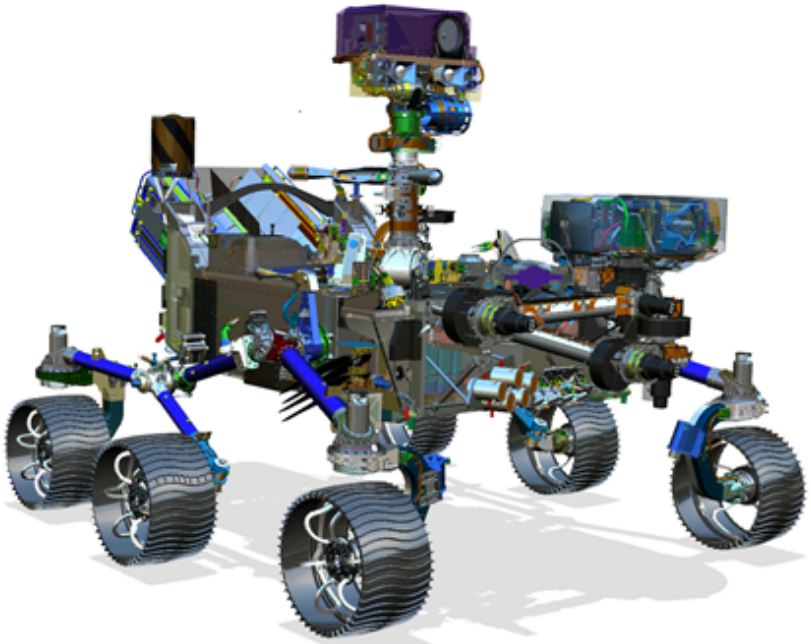
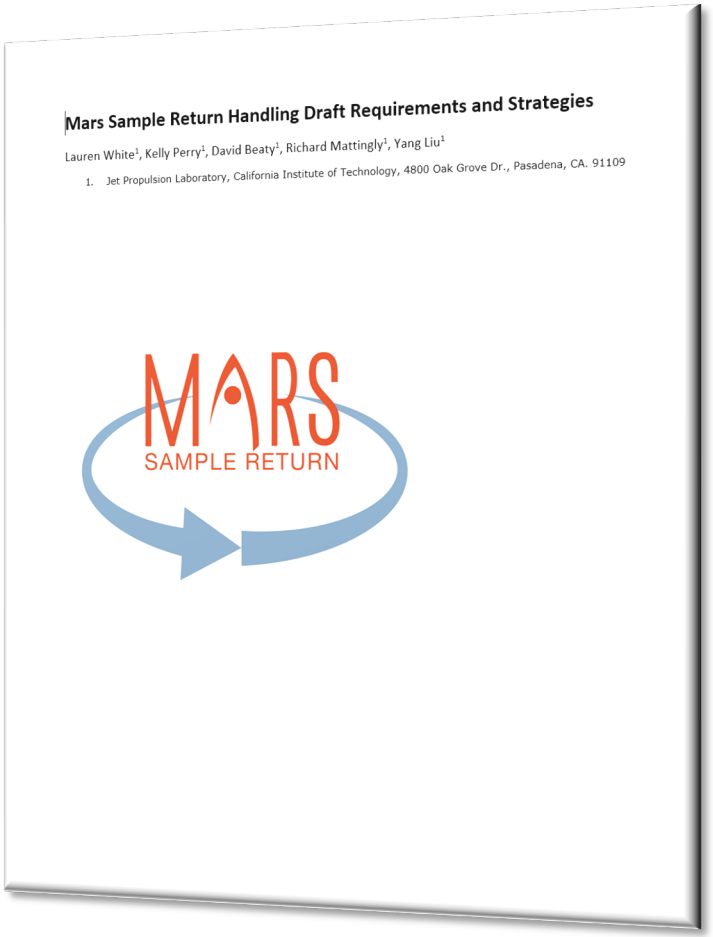


Mars 2020 Project

What's the point ?

- MSPG should focus on defining the requirements (or guidelines) for sample cleanliness and clearly separate these from *implementation*
  - e.g. "The Mars 2020 landed system shall be capable of encapsulating samples for return such that the organic contamination levels in each sample in the returned sample set are less than Any Tier 1 compound (organic compounds deemed as essential analytes for mission success): 1 ppb"
  - Implementation: ISO 5 cleanroom, no smokers allowed in the cleanroom, strict protocols for assembly, bake out of all hardware, etc.

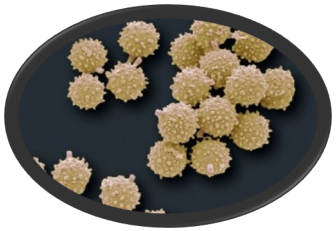


Mars2020 Cleanliness Requirements

Unlike any past NASA project, Mars 2020 has requirements to control ALL of the following contamination vectors:

Forward Planetary Protection

Spores

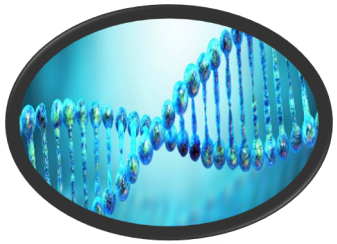


Note: not related to sample cleanliness

Return Sample Science

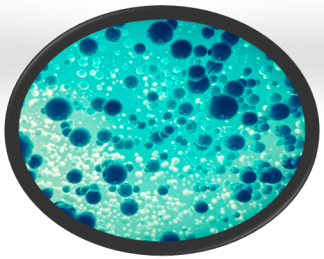
Viable Organisms (<1)

Genetic Inventory

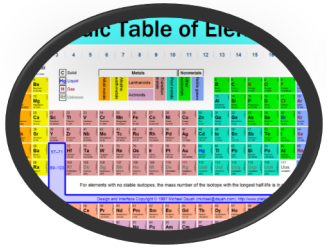


Outgassing (~1 ng/cm2/hr)

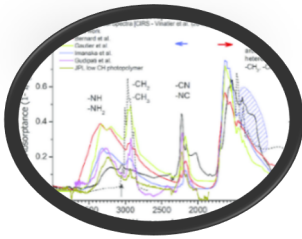
Particulate (PCL 50-300)



Total Organic Carbon
Tier 1 Compounds: 1 ppb
Tier 2: 10 ppb
TOC: 10ppb



Inorganics pg-mg of 34 elements



Non-volatile residue (<100 ng/cm2)

Planning Considerations Related to the Organic Contamination of Martian Samples and Implications for the Mars 2020 Rover, Astrobiology, Volume 14, Number 12, 2014

Not Covered by M2020

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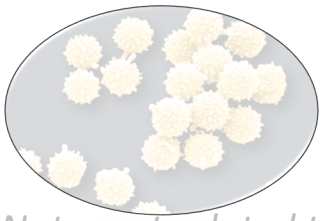

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Return Sample Science

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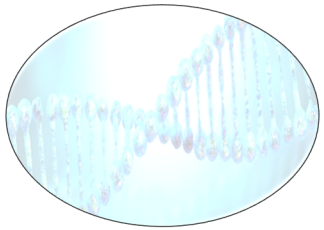

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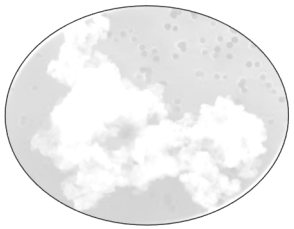

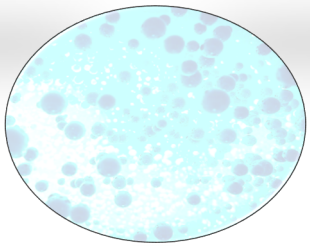

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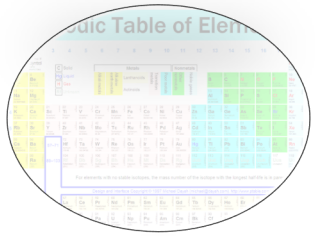

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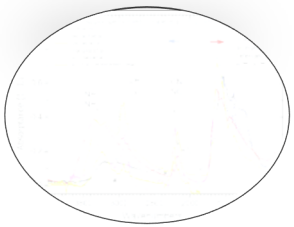
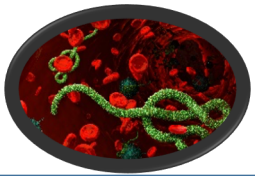


Non-volatile residue (<100 ng/cm2)

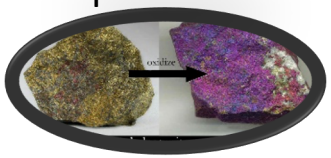
NOT covered by M2020

Sample extraction

Backward PP



Sample alteration



Key and Driving Contamination Requirements

- **Organic Carbon**
  - each sample limited to:
    - Any Tier 1 compound (a set of 16 target biomarker compounds thought to be indicative of Martian and/or terrestrial life; or directly interfere with our ability to assess the presence of extant or extinct life on Mars* :

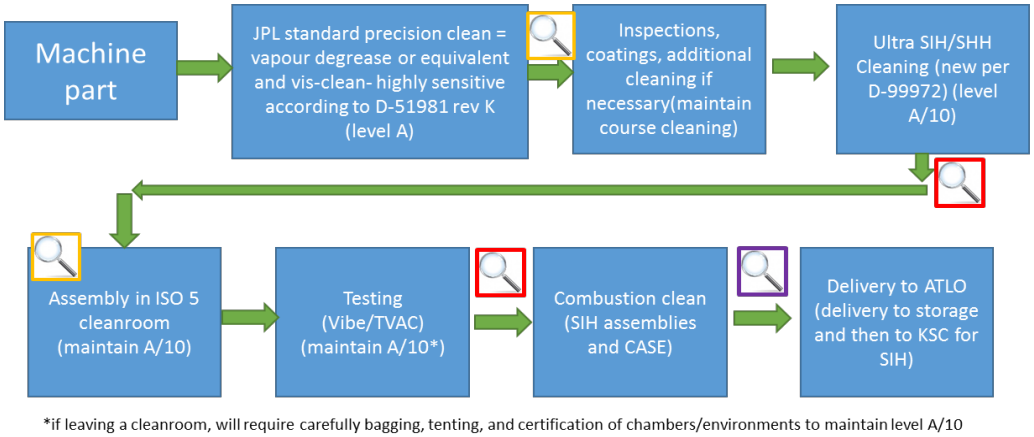
      1 ppb
    - Any Tier 2 compound (organic compounds not categorized as Tier 1): 10 ppb
    - Total Organic Carbon: 10 ppb
- **Viable Organism**
  - Each sample in the returned sample set has less than 1 viable Earth-sourced organism.
- **Inorganic Contamination**
  - Each sample limited to:
    - Less than 1% of the average concentration in SNC meteorite of following elements: Zr, Nb, Ta, La, Ce, Eu, Gd, Li, B, Cs, Sc, Mn, Y, Mg, Zn, Ni, Co, Cl, Br, P, S
    - Less than 0.1% of the average concentration in SNC meteorite of following elements:K, Rb, Sr, Sm, Nd, U, Th, Re, Os, Lu, Hf, W, Pb

* Summons, R.E., et. al. (2014) Planning considerations related to the organic contamination of martian samples and implications for the Mars 2020 rover. Astrobiology 14, doi:10.1089/ast.2014.1405.

Future analytical techniques employed to characterize returned samples is difficult to predict……

Mode of Operation

- Clean all hardware, tooling, GSE down to “ultra” cleaned levels
- VHP all tools and GSE
- Keep everything in an ISO 5 environment
- Use tools and GSE to hold/touch/assemble as much as possible (metal, or foil)
- Use “aseptic” protocols to interact/assemble hardware
- Combustion clean hardware to 0.3 ng/cm2 levels and 6-log reduction of biological contamination
- Strict controls over materials (even in hardware design) /solvents/cleanroom operations
- Bakeout ALL hardware

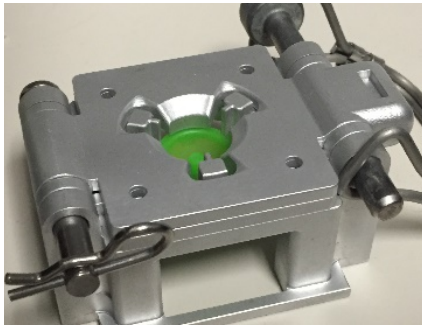


*if leaving a cleanroom, will require carefully bagging, tenting, and certification of chambers/environments to maintain level A/10

Cleanliness sampling (no halt in assembly flow)

Cleanliness sampling (assembly flow should wait for results)

Cleanliness sampling on proxy only (assembly flow should wait for results)



Follow the part…

Hardware: XXXX Part Number: XXXX Serial Number: XXXX

Sample Caching System (SIH/SHH) CC/PP Cleanliness Traveler
Mars 2020 Documentation
NASA JPL

A286 Hardware Without Dry Lubricants

HARDWARE: XXXXX
Part Number: XXXXXXXX
Serial Number: XXXXXXX

Hardware Cleanliness Requirements:

PCL: 50 **NVR: A/10**

Cognizant Personnel Responsible for Hardware:

Check One SIH ☐ SHH ☐

Name (Print): _____ **Initials:** _____ **Date:** _____
Role: _____

Name (Print): _____ **Initials:** _____ **Date:** _____
Role: _____

Name (Print): _____ **Initials:** _____ **Date:** _____
Role: QA Observer

The following traveler outlines procedures for cleaning and handling of this Mars 2020 hardware. **All steps are to be completed in order and not be omitted for any reason**. All work and verification in this document must be an accurate account in order to maintain science integrity and verification of hardware cleanliness. More detailed information for materials and procedures can be found in JPL D-99972 and JPL D-51981 REV K. By signing above, cognizant personnel agree to follow all procedures and standards to clean and handle Mars 2020 hardware.

The following materials must be used when performing these procedures:

- HPLC grade isopropyl alcohol (IPA) *filtered to 1.2 micron for final rinse*
- HPLC grade ethanol *filtered to 1.2 micron for final rinse*
- Analytical grade or better acetone, ethanol, or IPA 51981, D-99972 sonication only)
- Vertrel XF
- Oakite 61B
- Brulin 815 GD
- 18M-ohm deionized water (DI) water
- Cleanroom nitrile gloves (Ansell Nitrilite)
- Kimtech G3 Sterile Gloves
- Tools, cleaned per this precision clean process
- Metal canister for rinse solvent (model in D-99972)
- Grade C GN2 (IR certified, 0.2 micron filtered)
- Non-printed CP STAT 100 bags
- Pre-fired UHV aluminum foil (Allfoil)
- Vectra Alpha 10 TX1010 sealed border wipes
- Kapton tape (Permacel P224Y966 adhesive)

Hardware Handling:
Prior to precision cleaning, hardware may be handled with approved clean room gloves (listed above). Post precision cleaning, hardware must only be handled using sterile and precision cleaned tooling and/or minimal contact with Kimtech G3 gloves. Post combustion cleaning, only indirect contact with sterile and precision cleaned tooling or support hardware is allowed (no direct contact with gloves).

Hardware: XXXX Part Number: XXXX Serial Number:XXXX

Any visual observation of fingerprints, films, or particles requires re-cleaning of hardware prior to verification.

Precision Clean 1: Passivation per D-59181 During Part Assembly (Ansell Nitrile Glove Handling)

Step	Description	Complete	Initial	Date
Pre-Clean	Clean part per D-51981 methods indicated below: Type 1 Method (A, B, C, D, E) or Type 2 (Detergent Cleaned) Followed by: **Type 3 (Alkaline Cleaning)**			
Passivation	Perform passivation per D-51981. Check when complete. Type IV Nitric 1 Type IV Nitric 2 Type IV Nitric 3			

Precision Clean 2: Type 1 Method D per D-51981 Required by D-99972 Before Ultra Clean (Ansell Nitrile Glove Handling)

This section must be completed if passivation is not completed immediately before performing ultra cleaning. If passivation is completed immediately prior to ultra cleaning, skip this section and proceed to ultra cleaning.

Initial to the right to indicate that passivation was completed immediately before ultra cleaning.

Step	Description	Complete	Initial	Date
Immersion	Completely immerse parts in tank with minimum temperature of 18 °C (65 °F) with IPA.			
Sonicate	Soak part with sonication for a minimum of 2 minutes.			
Rinse	Rinse with IPA or DI water.			
Dry	Blow dry with Grade B or better nitrogen at a max temperature of 150 °F (66 °C).			

Ultra Cleaning Procedure per D-99972 (Sterile Tool Handling, Kimtech G3 Sterile Gloves Post Ultra Clean)

Step	Description	Complete	Initial	Date
Pre-wipe	Wipe hardware with Vectra Alpha 10 TX1010 sealed border wipes until no discoloration appears on wipe.			
Soak 1	Place hardware in ultrasonication unit with acetone. Fully submerge and orient so that particles fall out of hardware and into container. Place in ultrasonic bath. Soak for 3-5 minutes.			
Sonicate 1	Sonicate for 2-5 minutes in acetone.			
Drain 1	Drain all solvent from all cavities of hardware into beaker.			
Rinse 1	Rinse all surfaces with fresh solvent from designated canister filled with IPA or ethanol. Alcohol shall be filtered (submicron).			
Soak 2	Place hardware in ultrasonication unit with IPA or ethanol. Fully submerge and orient part so that particles fall out of the most sample intimate hardware and into container. Place in ultrasonic bath. Soak for 3-5 minutes.			
Sonicate 2	Sonicate for 2-5 minutes in IPA. See highlighted front page restriction.			
Change Gloves	Put on Kimtech G3 sterile gloves before removing hardware before sonication bath. These should be worn through packaging the hardware.			
Drain 2	Drain all solvent from all cavities of hardware into beaker.			
Rinse 2	Wet all surfaces with fresh solvent from metal canister filled with IPA or ethanol. Alcohol should be filtered (submicron). Collect final rinse (see next step)			
PCL Verification	Perform final rinse all in one step. Save 50 mL each from the total volume for PP and CC verification, and use the rest for PCL verification. (Saving sample for PP/CC is per batch not per part.)			
Dry	Forced GN2 blow off (not in fume hood, must be filtered).			

14

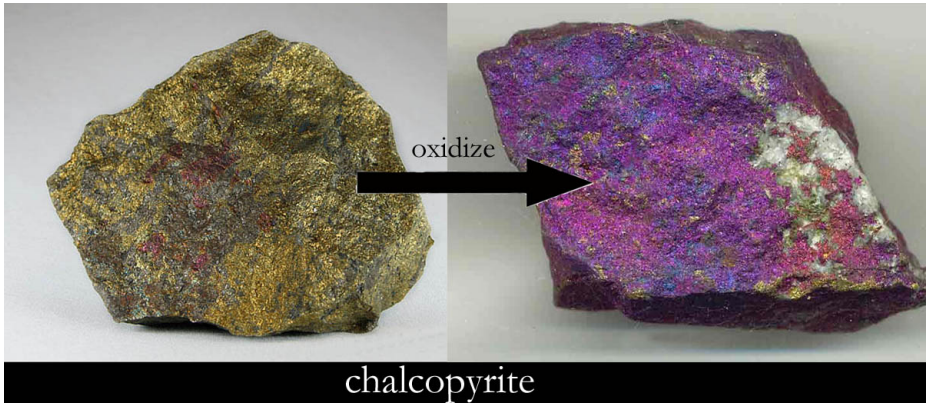
Document everything the part goes through

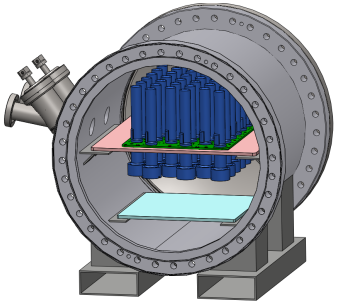
Verify cleanliness at the end (rinse only)

Indirectly verify cleanliness with witness plates following hardware

Disconnects between M2020 and SRF

- Samples will need to be protected again chemical alteration → likely means an air-free environments to protect against oxidation
- Does not control for backward Planetary Protection (e.g. a potentially pathogenic Mars virus) …. TBD at workshop #3
- TOC and VO relies on combustion cleaning of metal parts



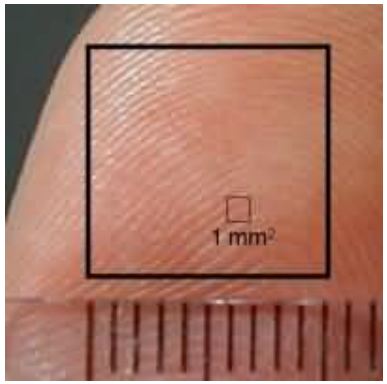


"CASE"

Biggest source of contaminants: Humans

Cleanrooms and associated Controlled Environments

- Biggest threat to hardware cleanliness is people
  - Skin flakes
  - Hair
  - Spittle droplets
  - Fingerprint residue
  - Clothing fibers
  - Cosmetics chemicals
  - Footwear dirt
  - Bacteria and viruses



10,000 bacteria on 1 cm^{-2} skin
100 bacteria on 1 mm^{-2} skin

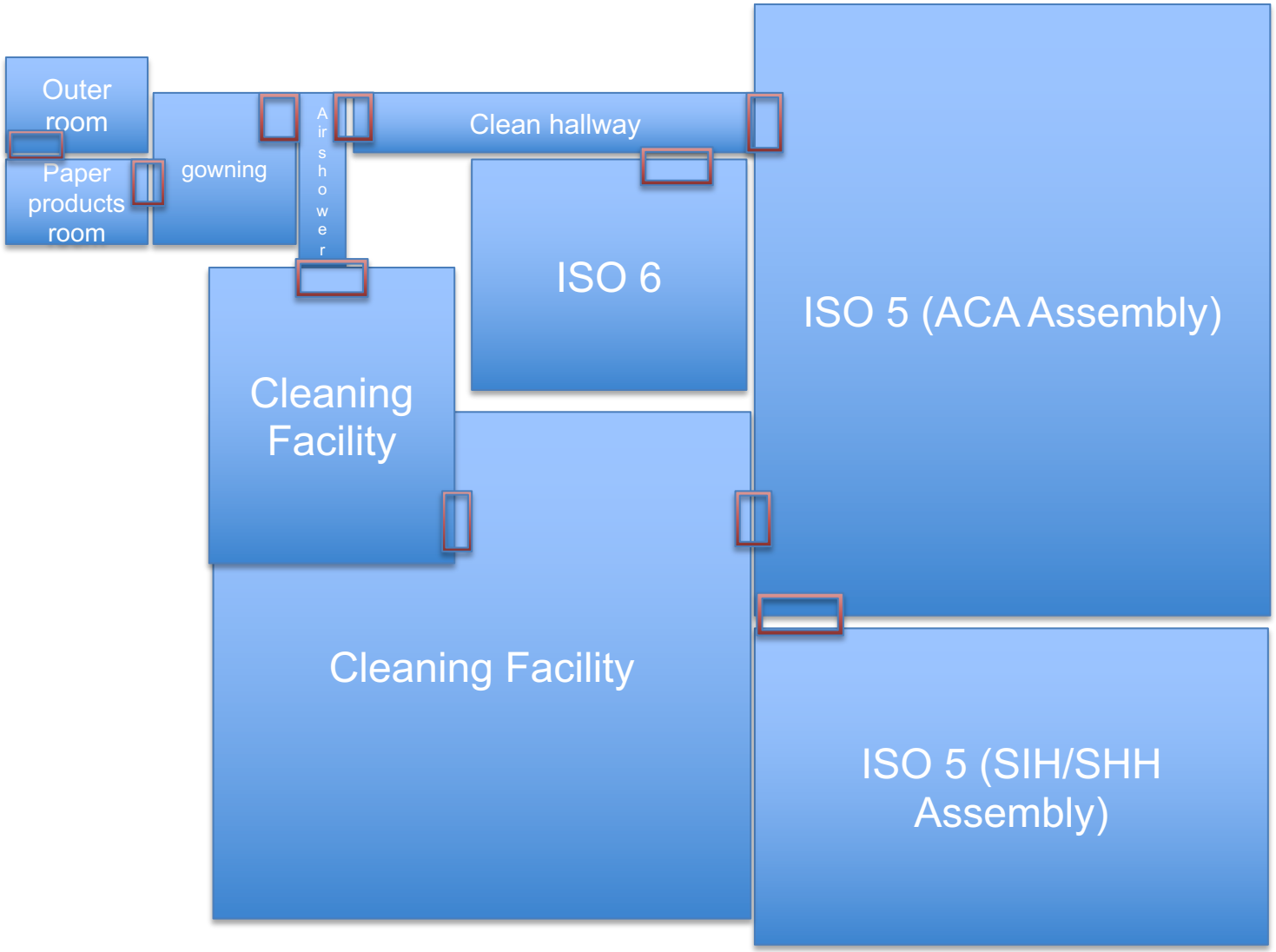
How clean do we really have to keep hardware ?

In order to achieve the levels described in the previous slide we MUST keep all SIH and SHH hardware clean to:

- <A/10 (100 ng/cm2) through the final firing bakeout (this is a monolayer of organic carbon on a surface)
- PCL 50-100 (depending on the hardware) (will break if exposed to anything above an ISO 5 environment)
- Sterility must be maintained at all times (non-sterile GSE or tools or the wrong gloves or solvents can change this)

Mars 2020 SCS Facilities

Go from clean to more clean to ultra clean as you step through the rooms

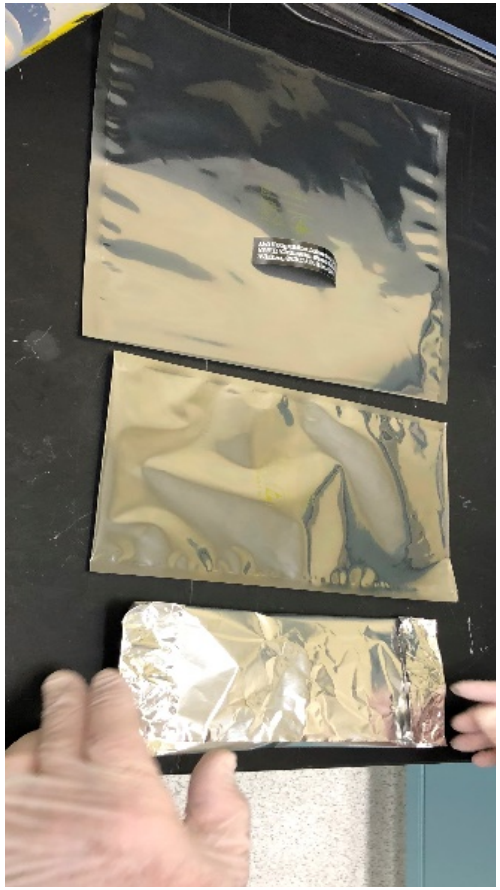


Examples of Protocols

All of the following items are **NOT ALLOWED** in these facilities

- Plastics
- Paint
- Paper (including cleanroom paper)
- Computers not “born in” cleanrooms
- Cell phone not “born in” cleanrooms
- Apply lubricants, epoxies, or perform soldering outside of designated area
- Use Kapton tape on ISO 5 flowbenches
- Introduce new equipment without CC and lead cleanroom tech approval
- desiccants

Materials

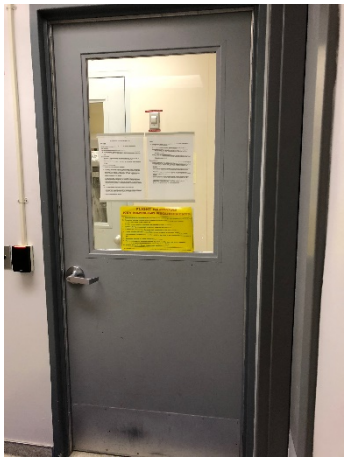


- Lot tested ESD bags, solvents, foil, gloves, EVERYTHING
- Pre-fired UHV foil
- Always fold foil over hardware then double bag and heat seal
  - Yes we tested the heat sealing!
- Only HPCL grade solvents in pre-conditioned Teflon bottles allowed
- All items in cleanroom go through “ultra” precision cleaning down to ~100 ng/cm2 and PCL 50 level (biologically clean as well)

Entrance Room VS. Gowning Room

Pre-Entrance Room

Entrance Room



Breezeway

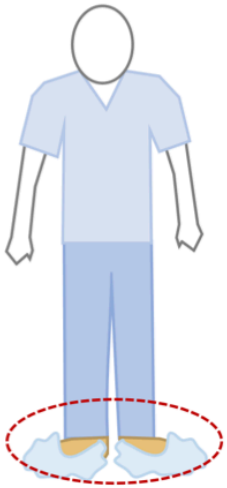
Main Gowing Room (immediately from breezeway)

Main Gowning Room (to the left upon entry)

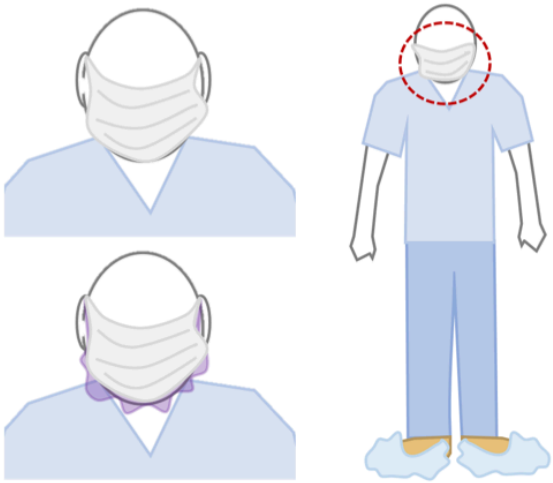
Cleanroom Gowning Review

Entrance Room (pre-gowning)

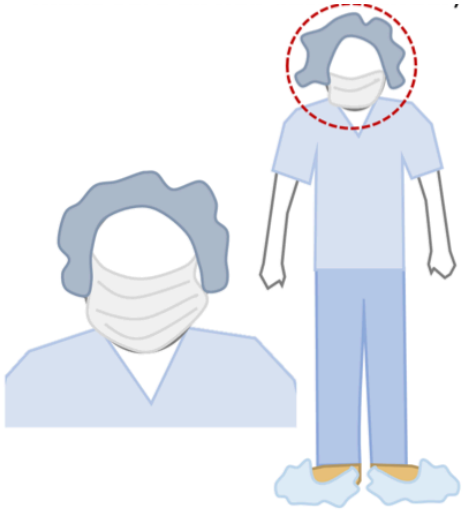
1. Clean off shoes with shoe brush cleaner. Put on foot covers and walk across the tacky mat before entering breezeway.



2. Face mask (covering nose & chin). If needed, wear beard mask BEFORE putting on the face mask.



3. Hair net (cover ears and make sure all hair tucked under).

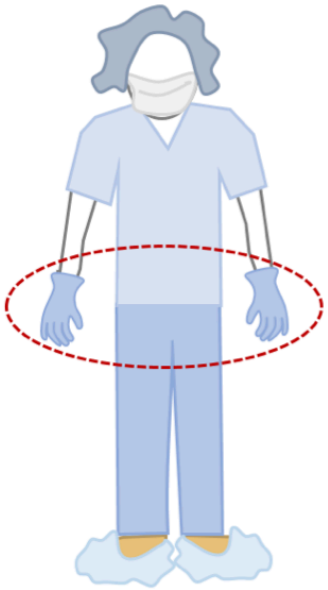


Storage of items in the entrance room will be limited. Do not plan to store your items in this area. Be sure to leave them in your office instead.

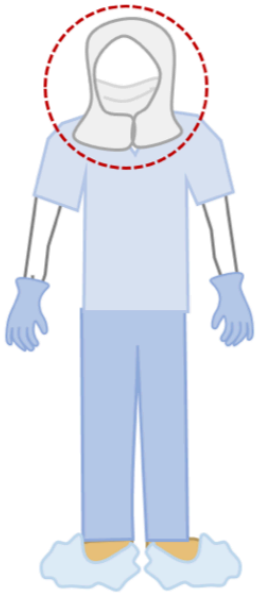
Cleanroom Gowning Review

Gowning Room (sterile environment)

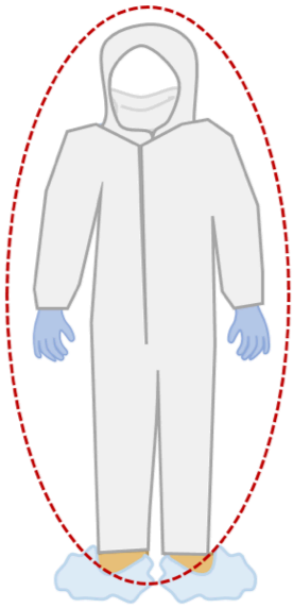
1. First glove pair, to ensure garments are handled with clean gloves.



2. Place hood over hair net. No hair should be visible.



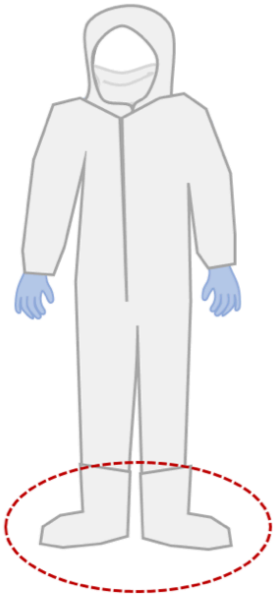
3. Bunnysuit. Step into the suit, do not let sleeves or legs touch the floor. Ensure that hood is fully tucked into the suit.



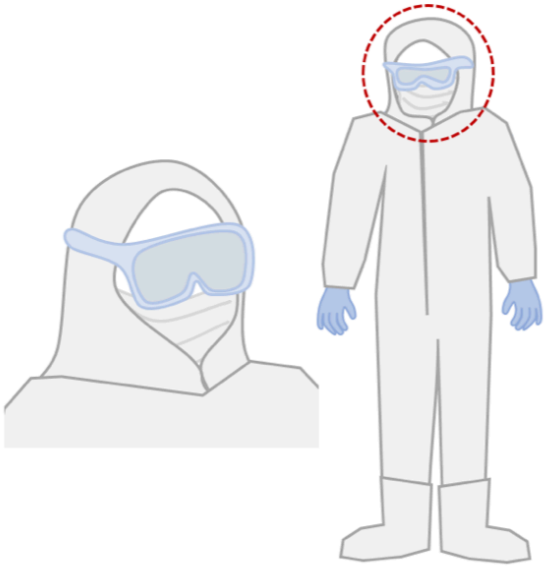
There will be no storage of items in this area. Only bring in what you absolutely must for the cleanroom (e.g. prescription glasses). All these items must be wiped down as well.

Cleanroom Gowning Review

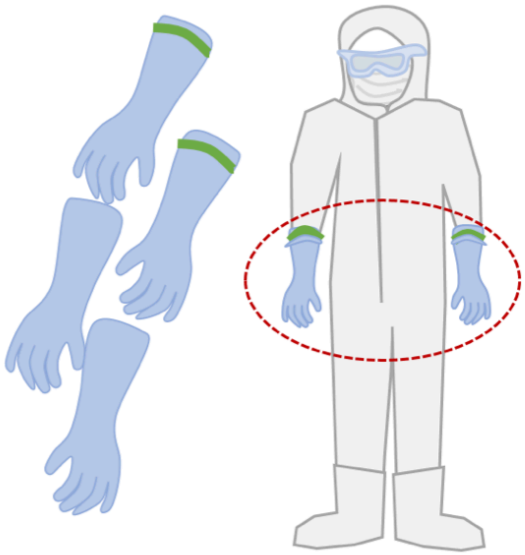
4. Put on the boot covers with the suit tucked into the boots. Fasten all the straps.



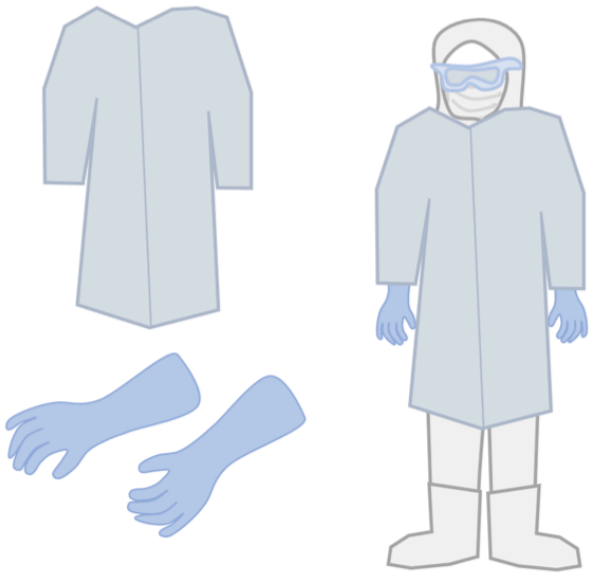
4. If 151, you may grab a pair of sterile goggles in the garment room or immediately before 151. These will be put on before entering 151 with a secure fit of the goggle straps around the head to prevent slippage.



5. All personnel will tape the first pair of gloves on. If 151: place a second glove pair on after taping. Tape should be half on the glove, half on the garment to ensure a tight seal.



Cleanroom Gowning Review



If entering 233-151, personnel must wear an additional smock over jump suit. The sterile smock and goggles will be put on immediately before entry to 151. The gowning area for this will be in front of the 151 entrance.

Do not hang around or do work in the sterile gowning area.

Examples of Protocols

All of the following items are **NOT ALLOWED** as personnel actions, attire, or general activities in 233-140, 141 and 151:

- Improper cleanroom attire or incorrectly worn attire (cover your nose!)
- Exceeding the max number of people allowed for a cleanroom
- Smoking within 48 hrs of assembling hardware
- Excess item storage forbidden from entrance room (before gowning room)
- Jewelry or personal phones
- Make up, skincare, and artificial nails
- Working without double gloves
- Horseplay and rapid movements
- Personal cell phones

Hygiene and Pre-Gowning

- Do not use “smelly” lotions or deodorants
- Hair product (shampoo/conditioner, hair gel/mousse/spray), after shave, and and fragrance shall not be used within 12 hrs of entering the cleanroom
- Minimize facial hair or use beard net
- No eating, drinking, smoking, gum chewing, and combing of hair in the gowning room or cleanrooms
- If you are clearly sick, or frequently coughing or sneezing. Do not come to work!

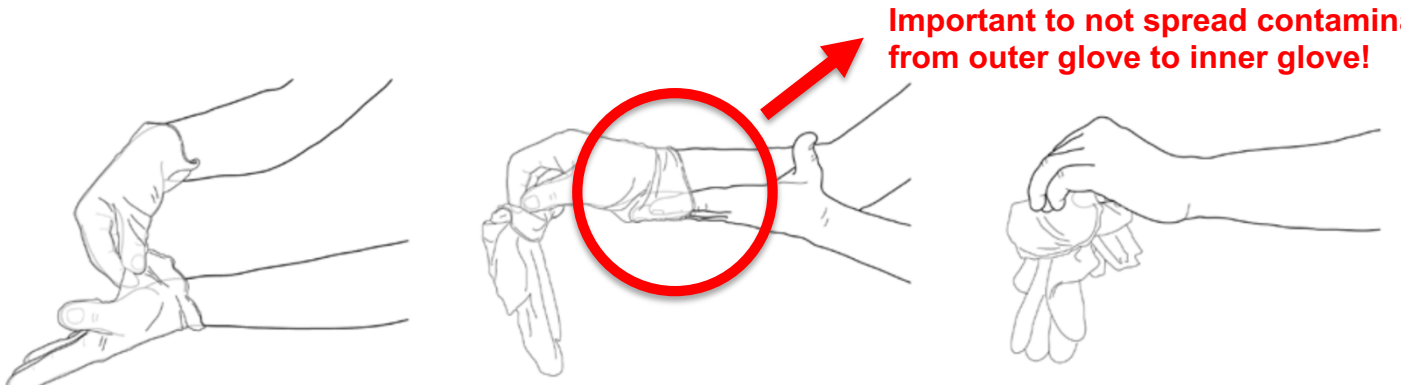
If your hair looks this stylish and smells great, you will not be allowed to work in the cleanrooms that day

Examples of Protocols

- **<u>Gloves should not be changed in or in close proximity to flight hardware</u>**

- This creates unnecessary risk of particles and organics being distributed to critical hardware!

- If there is a need to change your second glove pair:
  1. Walk at least three feet from the hardware
  2. Turn your back to the hardware
  3. Change your gloves by removing the top glove layer as shown below
  4. If you transfer contamination to your inner glove from your outer glove, you must leave the cleanroom to change the inner gloves. Be sure to de-glove the outer pair properly!



(This image and technique is from the World Health Organization)

Mars 2020 Cleanrooms

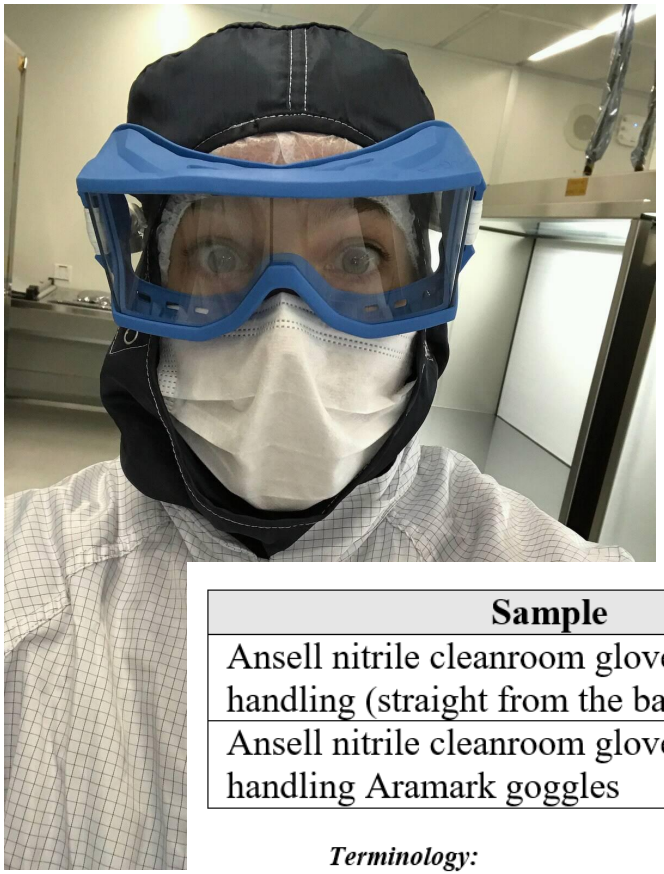
Mars 2020 Cleanrooms

Mars 2020 Cleanrooms

Biological vs Organic Controls

Post autoclaved parts

Biological v Organic Controls



By –
Julia Griffin

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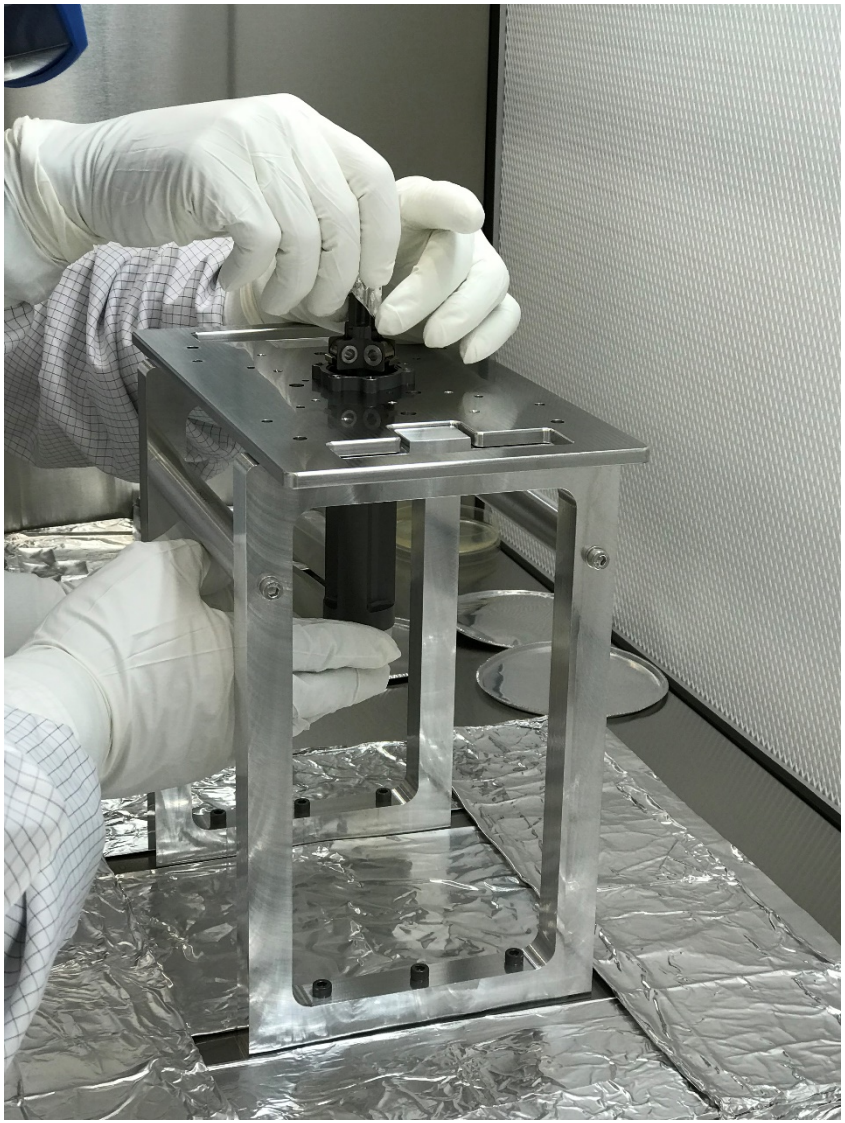
comments

Meet the mite, the tiny bugs in your mattress, your tea and on your face

Sample	Chemical Functional Group	Total Amount (µg/cm^2)
Ansell nitrile cleanroom glove - no goggle handling (straight from the bag)	AHC	< 0.02
Ansell nitrile cleanroom glove - after handling Aramark goggles	AHC (~ 96%), Silicone (~ 4%)	0.05

Terminology:
AHC: Aliphatic Hydrocarbons, base oil of lubricants, additives
Silicone: polydimethyl siloxane, commonly from RTV silicone, release agents, processing agents
Ester: common plasticizer and polymer components
µg/cm^2: micrograms per square centimeter

Example of Assembly



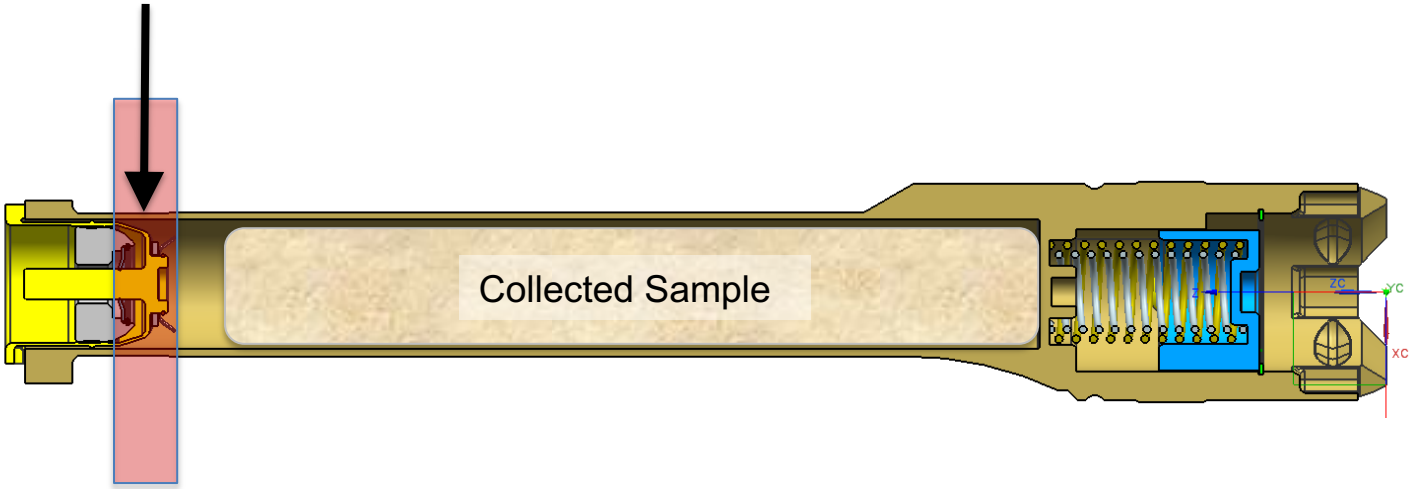
Results

- All hardware in these facilities is meeting cleanliness requirements:
  - <0.02 ug/cm2 (requirement is <0.1 ug/cm2)
  - PCL 50-100
  - Sterility requirements (< 1cfu/25cm2)

- Biggest Challenges:
  - Break down of facilities
  - The little things – e.g. fiberglass insulation in a thermal chamber
  - Culture change in cleanrooms
  - Solutions that work for ALL RSSC vectors (organic, inorganic, biological, etc)

Sample Extraction

1. Sampling headspace gas



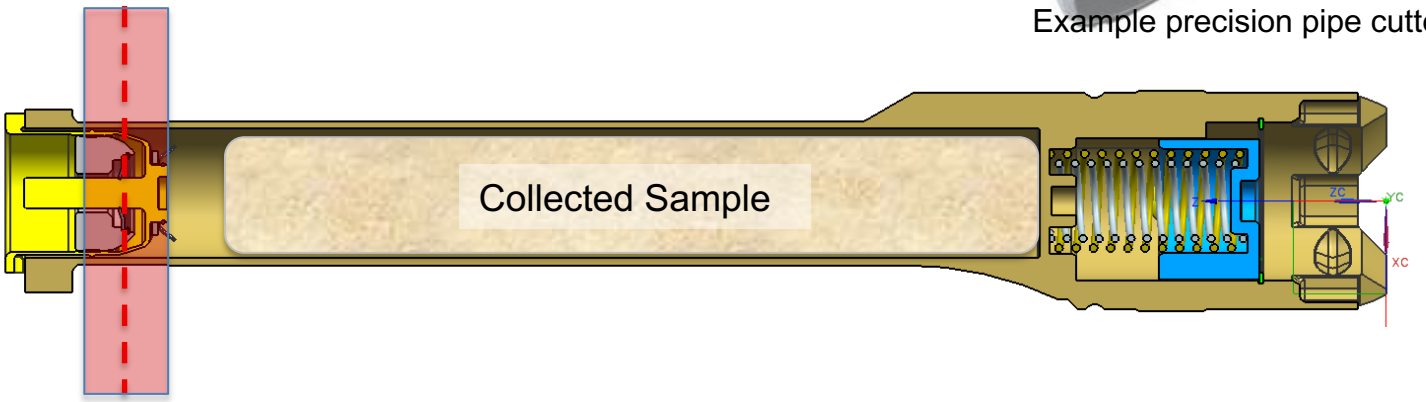
1. Machine the exposed TiN neck of the tube down to a thin layer (0.1-25 mm)
2. Clean exterior of tube of contaminants
3. Puncture hole in edge of sample tube between seal cup and sample using hollow-tipped awl connected to a hose

Example hollow awl – remove plastic, add hose to back end

2. Opening the end

Cut sample radially with passive cutting wheel in this zone

Example precision pipe cutter

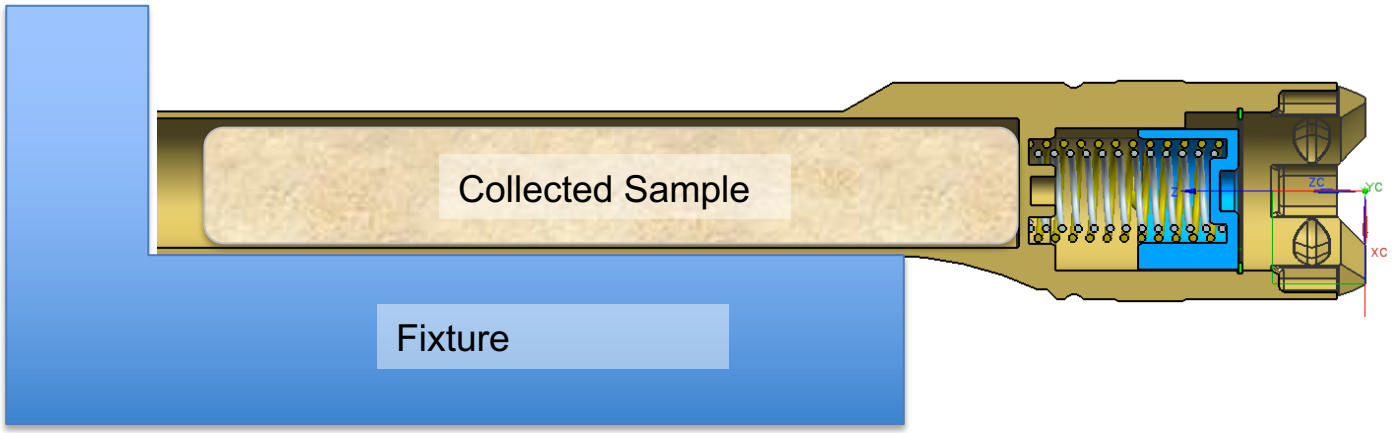


De-burr and expand edges

- Often, cut tubes can display burrs or a decrease in ID at the cut surface
- Smooth the inner surface to allow for gentle extraction

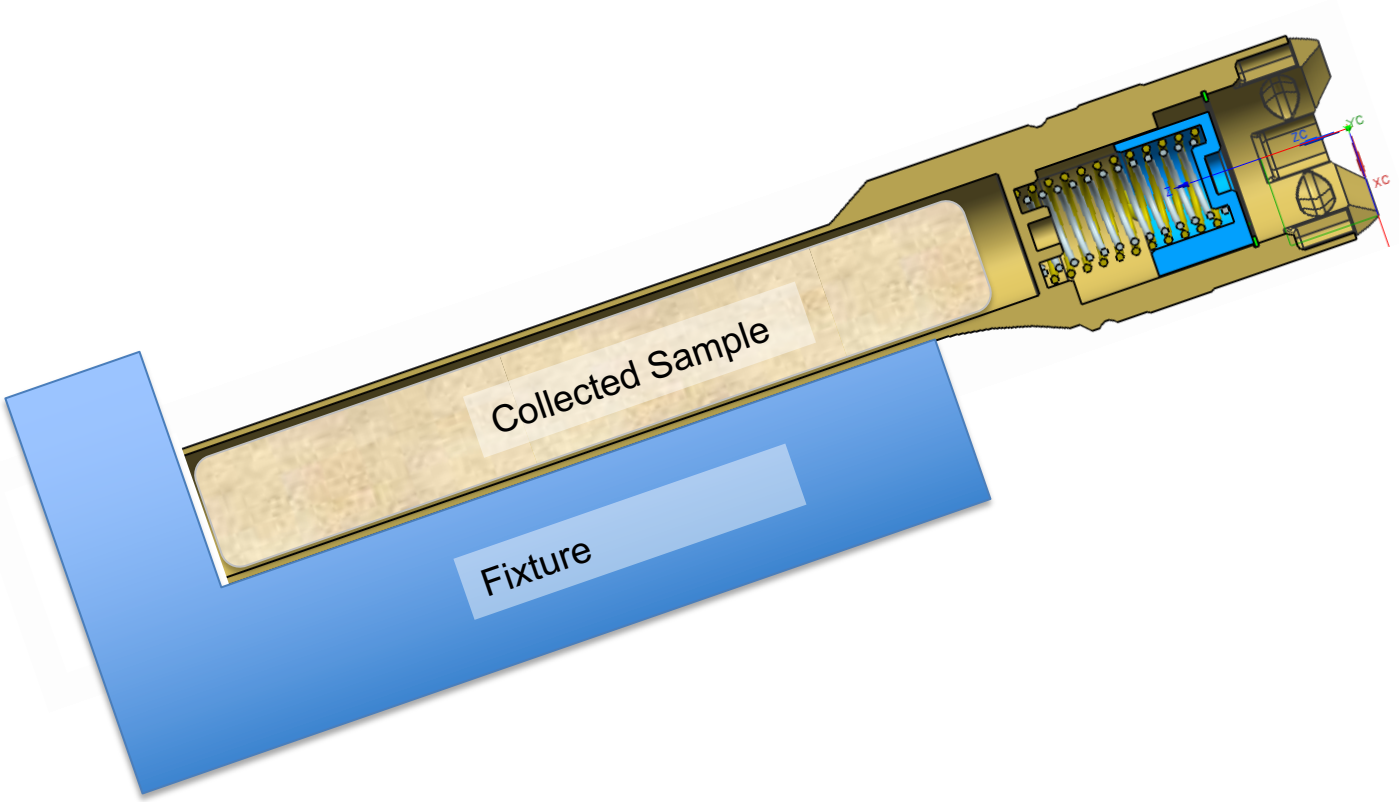
End-Opening Strategy

- Rest tube in fixture



End-Opening Strategy

- Tilt, causing sample to slide out in collector with sample seated against edge

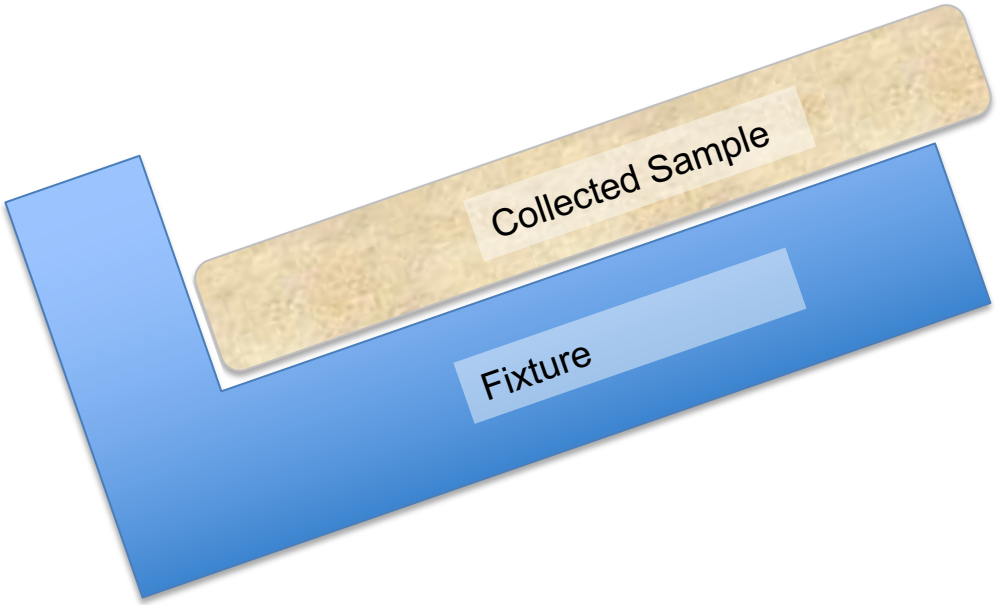


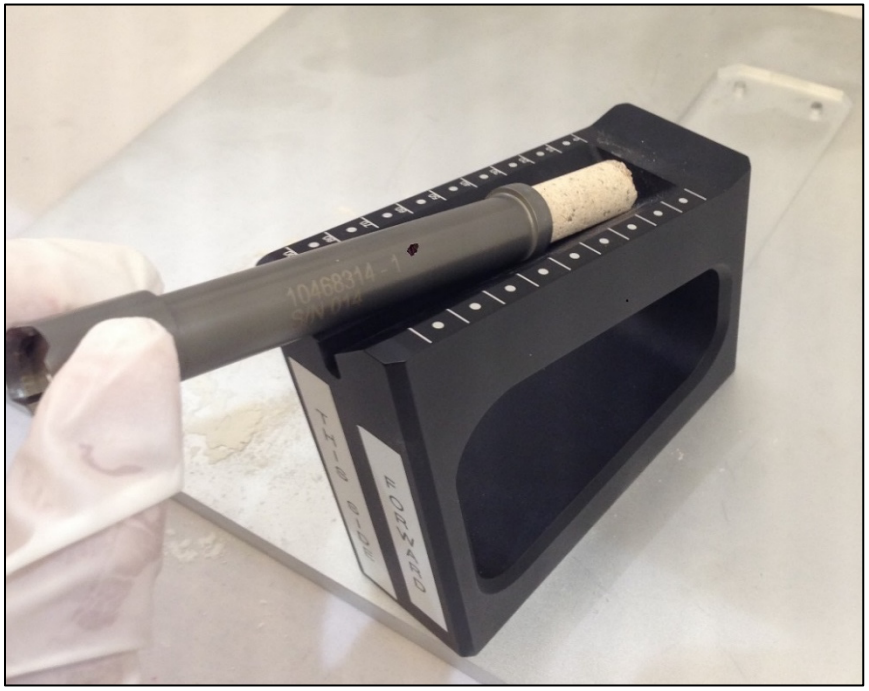
End-Opening Strategy

- Pull tube away from sample, agitating slightly, while keeping sample seated against base of collector

End-Opening Strategy

- Pull tube away from sample, agitating slightly, while keeping sample seated against base of collector






THIS SIDE
FORWARD

Summary

- Mars 2020 has paved the way for finding materials, protocols, cleaning specs, etc to meet all contamination vectors on hardware surfaces
- Much of this could be translated to SRF for facility cleanliness and maintenance
- Only minimal development for
  - Sample extraction
  - Sample alteration
- All contamination vectors will likely need to be met in this one space and we need to identify potential overlap/difficult areas
- We should clearly identify requirements vs implementation since there are many ways to maintain cleanliness

Ideas for Workshop #2

- Focus on:
  - Requirements for sample cleanliness (start with M2020 return sample requirements)
  - Separate requirements from implementation
  - Sample extraction
  - Sample alteration prevention
  - Areas where contamination vectors work against each other logistically (identify trouble areas of overlap)

- backup

Organic Carbon L1 and L2

#	Topic	Text
L1-15	Organic Carbon	The Mars 2020 landed system shall be capable of encapsulating samples for return such that the organic contamination levels in each sample in the returned sample set are less than: • Any Tier 1 compound (organic compounds deemed as essential analytes for mission success): 1 ppb • Any Tier 2 compound (organic compounds not categorized as Tier 1): 10 ppb • Total Organic Carbon: 10 ppb Baseline, 40 ppb Threshold
L2PS - 44380	Organic Carbon	Same as L1 Baseline

Viable Organisms at L1 and L2

#	Topic	Text
L1-17	Viable Organisms	The Mars 2020 landed system shall be capable of encapsulating samples for return such that each sample in the returned sample set has less than 1 viable Earth-sourced organism.
L2PS - 72265	Probability of viable Earth organism in returned sample	The Mars 2020 Project shall be capable of encapsulating samples for return such that each sample in the returned sample set has more than a 99.9% probability of being free of any viable Earth-sourced organisms.

- Note that the level 2 requirement is tighter than the Level 1 requirement by a factor of 1000

Inorganic Contamination at L2

#	Topic	Text	Note
L2PS - 63993	Inorganic Contamination at 1% (of SNC)	The PS shall limit contamination of rock samples with Earth-sourced inorganic contaminants to no more than the contamination mass limits listed in Table IOC (all values TBC) for… Zr, Nb, Ta, La, Ce, Eu, Gd, Li, B, Cs, Sc, Mn, Y, Mg, Zn, Ni, Co, Cl, Br, P, S	Holding the TBCs until completion of inorganic test program now underway See Inorganic Vectors presentation for Table IOC
L2PS - 63994	Inorganic Contamination at 0.1% (of SNC)	The PS shall limit contamination of rock samples with Earth-sourced inorganic contaminants to no more than the contamination mass limits listed in Table IOC (all values TBC) for… K, Rb, Sr, Sm, Nd, U, Th, Re, Os, Lu, Hf, W.	
L2PS - 63995	Inorganic Contamination: Lead	The PS shall limit contamination of rock samples with Earth-sourced Pb contaminants to no more than the Pb contamination mass limit listed in Table IOC. (Value TBC)	